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ORIGINAL MEMOIRS.

DRY IODINE CATGUT.[1]

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ABOUT one year ago I presented to the Surgical Section of the New York Academy of Medicine a brief report[1] on Claudius's catgut, in which I pointed out its advantages over catgut prepared by other methods. This method of preparation was soon adopted by surgeons in various parts of the country, and it was not long before I received various complaints concerning its tensile strength; and it is but proper to confess that, though we continued to use it, we also found that this complaint was not entirely without foundation. Its other advantages were, however, so preponderating, that, though not satisfactory in all details, we were loath to abandon it entirely, and I therefore set myself the task to find, and if possible to eliminate, the causes of this loss of strength. I soon became convinced that this was due only to its long-continued immersion in the iodine solution. In other words, no change was necessary in the preparation of the catgut, but one was indi-

[1] Read before the Surgical Section of the New York Academy of Medicine, May 5, 1905.

cated in its subsequent preservation. According to Claudius's directions, the catgut was preserved in the original iodine solution for an indefinite time. I have changed these directions in so far that I remove the catgut from the iodine solution at the end of eight days, and thereafter keep it dry and ready for use in a sterile vessel. This step, however, be it ever so simple, involved to my mind a material departure from Claudius's method, and it was necessary therefore to again subject the dry catgut to an investigation of the attributes required of good catgut; and it is the object of this paper to present the results of my research.

As I pointed out in my original article, the four cardinal attributes which must be present in an ideal catgut are, (1) It should be absolutely sterile; (2) in the course of preparation it should not lose any of its tensile strength; (3) it should be readily and simply prepared, and without any undue expense, and (4) it should be absorbed completely, but only after it has served the purposes for which it was intended.

1. STERILITY.—Dr. Arpad G. Gerster and myself have used in the First Surgical Division of Mount Sinai Hospital as a routine procedure catgut prepared by means of iodine solution for nearly three years; during the past nine months after the modified method; and in no case have we had the slightest occasion for regretting our confidence in it. What is of practical interest at the present time is our experience with the newer catgut, and I can only say, that during the time mentioned we have used it in every instance where the use of catgut was indicated, not only as ligature, but also as suture material, and at no time did we see any untoward effects from it.

As already stated, the method now in use is to my mind an important departure from the original method of Claudius. Sufficient evidence for the sterility of catgut prepared by the Claudius method was presented by Claudius,[2], [3] Martina,[4] von Hippel,[5] and Johnson;[6] but it was necessary to examine the newer catgut also from a bacteriological stand-point. A few preliminary experiments were made for me by Dr. Alfred Cohn, of the house staff of Mount Sinai Hospital; the detailed

experiments I was able to conduct at the Pathological Laboratory of the College of Physicians and Surgeons, Columbia University, through the courtesy of Dr. T. Mitchell Prudden; and I take great pleasure on this occasion to express my gratitude to Dr. Prudden, not only for the many courtesies extended, but also for his valuable advice and for the interest shown in my work.

At the outset, I would state that all of the experiments were conducted with No. 1 iodine catgut, and that all of the experiments were controlled with catgut of similar size, prepared after the von Bergmann method.

The various experiments conducted may be conveniently grouped under the following headings:

A. *Tests to prove the sterility of the catgut.*

B. *Tests to show the effect of catgut on growing cultures.*

C. *Tests to show the effect of infected catgut.*

A. *Tests to prove the Sterility of the Catgut.*—These experiments were conducted in the following manner. Pieces of iodine catgut and of von Bergmann catgut, about one inch in length, were placed in the following media: Bouillon, gelatin (previously liquefied and poured into a Petri dish), agar-agar (previously liquefied and poured into a Petri dish), and serum-bouillon; the gelatin plates were kept at room-temperature, the remainder in the thermostat, and all were observed from day to day for about two weeks.

Following is an account of these experiments:

EXPERIMENT 1.—December 30. Iodine gut planted into bouillon. December 31, no growth. January 1, no growth. Observations taken until January 14, up to which date there was not the slightest clouding of the medium noted.

EXPERIMENT 2.—December 30. Von Bergmann catgut planted into bouillon. December 31, no growth. January 2, growth, as shown by cloudiness of the medium. Observations taken until January 14, but no further change noted.

EXPERIMENT 3.—December 30. Gelatin was liquefied and poured into a Petri dish; after solidification, a piece of iodine gut was placed upon it. December 31, no growth, nor at any time until January 7, when further observation was discontinued.

EXPERIMENT 4.—December 30. Gelatin was liquefied and poured into

a Petri dish; after solidification, a piece of von Bergmann catgut was placed upon it. December 31, no growth. January 2, no growth. January 3, one colony at great distance from the catgut. (Accidental contamination.) Observations taken until January 7, but no further change noted.

EXPERIMENT 5.—Agar-agar was liquefied and poured into a Petri dish; after solidification, a piece of iodine gut was placed upon it. December 31, no growth. January 2, no growth, nor at any time until January 10, when further observation was discontinued.

EXPERIMENT 6.—December 30. Agar-agar was liquefied and poured into a Petri dish; after solidification, a piece of von Bergmann catgut was placed upon it. December 31, no growth. January 2, no growth, nor at any time until January 10, when further observation was discontinued.

EXPERIMENT 7.—December 30. Equal parts of hydrocele-serum and bouillon were mixed, and into this mixture a piece of iodine gut was placed. December 31, no growth, nor at any time until January 14, when further observation was discontinued.

EXPERIMENT 8.—December 30. Equal parts of hydrocele-serum and bouillon were mixed in a test-tube, and into this mixture a piece of von Bergmann catgut was placed. December 31, no growth. Observations taken until January 10, when the medium became turbid, and remained so until January 14, when further observations were discontinued.

EXPERIMENT 9.—December 31. Repetition of Experiment 1; remained sterile until January 14, when further observation was discontinued.

EXPERIMENT 10.—December 31. Repetition of Experiment 2. January 2, no growth. January 3, medium turbid. Observations taken until January 14, but no further change noted.

EXPERIMENT 11.—December 31. Repetition of Experiment 3; remained sterile until January 10, when further observation was discontinued.

EXPERIMENT 12.—December 31. Repetition of Experiment 4. January 2, growth beginning at one end of the catgut, and therefore might be looked upon as a contamination. January 3, the entire plate was overgrown. Observations continued until January 7, but no further change noted.

EXPERIMENT 13.—December 31. Repetition of Experiment 5; remained sterile until January 10, when further observation was discontinued.

EXPERIMENT 14.—December 31. Repetition of Experiment 6; remained sterile until January 10, when further observation was discontinued.

EXPERIMENT 15.—December 31. Repetition of Experiment 7; remained sterile until January 14, when further observation was discontinued.

EXPERIMENT 16.—December 31. Repetition of Experiment 8; re-

mained sterile until January 14, when further observation was discontinued.

It might be argued by some that the iodine catgut, owing to its imbibition with iodine, is so powerful that in a measure it sterilizes the comparatively small amount of bouillon in a test-tube; to refute this argument, I have a number of times repeated the above experiments with iodine gut, but used for each experiment a much larger quantity (60 cubic centimetres) of bouillon, but in no instance did I obtain a growth.

In summing up these sixteen experiments, it is at once evident that all the tests made with the iodine gut remained sterile; some of the tests made with the von Bergmann catgut showed a growth, notably those made with bouillon (Experiments 2 and 10). The von Bergmann catgut is not on trial here, but in view of these tests it certainly shows an inferiority. Suffice it to say that these experiments justify at least the positive conclusion that the iodine catgut is sterile.

B. *Tests to show the Effect of the Catgut on growing Cultures.*

EXPERIMENT 52.—January 10. A tube of agar-agar was liquefied, infected with Bacterium coli, and poured into a Petri dish. After solidification, a piece of iodine catgut was placed upon it. January 11, numberless colonies developed, but none in a space three-quarters of an inch wide surrounding the catgut. January 12, the only change noted was an increase in the size of some of the colonies at the margin of the clear space. Observations taken until January 16, but no further change noted. (See illustration.)*

EXPERIMENT 53.—January 10. A tube of agar-agar was liquefied, infected with Bacterium coli, and poured into a Petri dish. After solidification, a piece of von Bergmann catgut was placed upon it. January 11, growth everywhere upon the plate, except in a space about three-sixteenths of an inch in width surrounding the catgut. Observations taken until January 16, but no further change noted. (See illustration.)

EXPERIMENT 54.—January 10. A tube of agar-agar was liquefied, infected with Staphylococcus aureus, and poured into a Petri dish. After solidification, a piece of iodine gut was placed upon it. January 11, numberless colonies upon the plate, except in a space about two inches wide surrounding the catgut. Observations taken until January 16, but no

* Dr. Edward Leaming was kind enough to make for me the photographs accompanying this article, for which I wish to express my thanks also on this occasion.

material change noted, excepting an increase in the size of the colonies near the margin of the clear space. (See illustration.)

EXPERIMENT 55.—January 10. A tube of agar-agar was liquefied, infected with Staphylococcus aureus, and poured into a Petri dish. After solidification, a piece of von Bergmann catgut was placed upon it. January 11, numberless colonies everywhere, excepting in a space about one-eighth of an inch in width surrounding the catgut. Observations taken until January 16, but no further change noted. (See illustration.)

EXPERIMENT 60.—January 10. A tube of gelatin was liquefied, infected with Bacterium coli, and poured into a Petri dish. After solidification, a piece of iodine gut was placed upon it. January 11, no growth. January 12, numerous colonies, excepting in a space about two inches wide surrounding the catgut. Observation continued until January 16, but no further change noted.

EXPERIMENT 61.—January 10. A tube of gelatin was liquefied, infected with Bacterium coli, and poured into a Petri dish. After solidification, a piece of von Bergmann catgut was placed upon it. January 11, numberless colonies everywhere, excepting in a space about one-quarter of an inch wide surrounding the catgut, and even here a few isolated colonies are to be seen with the microscope. Observations taken until January 16, but no further change noted except an increase in the size of some of the colonies.

EXPERIMENT 62.—January 10. A tube of gelatin was liquefied. [illegible] fected with Staphylococcus aureus, and poured into a Petri dish. After solidification, a piece of iodine catgut was placed upon it. January 11, no growth. January 12, numerous colonies, excepting a space about two inches wide surrounding the catgut. Observations taken until January 16, but no further change noted.

EXPERIMENT 63.—January 10. A tube of gelatin was liquefied, infected with Staphylococcus aureus, and poured into a Petri dish. After solidification, a piece of von Bergmann catgut was placed upon it. January 11, no growth. January 12, numerous colonies, except in a space about one-quarter of an inch in width surrounding the catgut. January 13, colonies almost up to the catgut. Observations taken until January 16, but no further change noted.

EXPERIMENT 111.—January 16. A tube of agar-agar was liquefied, infected with Bacillus anthracis, and poured into a Petri dish. After solidification, a piece of iodine gut was placed upon it. January 17, numerous colonies, but none within two and one-quarter inches of the catgut. January 18, a large number of isolated colonies developed within the space previously clear, but none within a space of one inch surrounding the catgut. Observations taken until January 21, but no further change noted. (See illustration.)

EXPERIMENT 112.—January 16. A tube of agar-agar was liquefied, infected with Bacillus anthracis, and poured into a Petri dish. After solidification, a piece of von Bergmann catgut was placed upon it. January 17, numerous colonies, excepting in a space about one-half inch wide,

No. 52. Agar infected with Bacillus coli, with iodine gut on top.
No. 53. Agar infected with Bacillus coli, with von Bergmann gut on top.

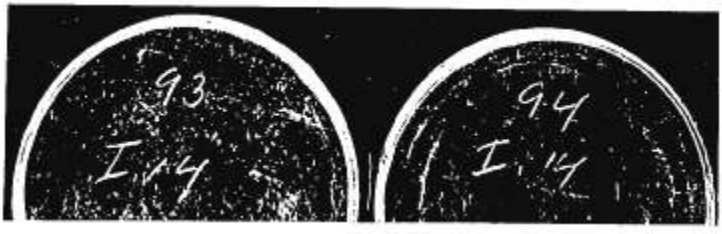
No. 54. Agar infected with Staphylococcus aureus, with iodine gut on top.
No. 55. Agar infected with Staphylococcus aureus, with von Bergmann gut on top.

No. 111. Agar infected with Bacillus anthracis, with iodine gut on top.
No. 112. Agar infected with Bacillus anthracis, with von Bergmann gut on top.

No. 56. Smears of Bacillus coli on agar, with iodine gut on top.
No. 57. Smears of Bacillus coli on agar, with von Bergmann gut on top.

No. 58. Smears of Staphylococcus aureus on agar, with iodine gut on top.
No. 59. Smears of Staphylococcus aureus on agar, with von Bergmann gut on top.

No. 68. Smears of Staphylococcus aureus on agar, with iodine gut on top.
No. 69. Smears of Staphylococcus aureus on agar, with von Bergmann gut on top.



No. 93. Smears of Bacillus anthracis on agar, with iodine gut on top.
No. 94. Smears of Bacillus subtilis on agar, with von Bergmann gut on top.

No. 95. Smears of Bacillus subtilis on agar, with iodine gut on top.
No. 96. Smears of Bacillus subtilis on agar, with von Bergmann gut on top.

surrounding the catgut. Observations taken until January 21, but only a slight extension of the colonies noted. (See illustration.)

EXPERIMENT 113.—January 16. A tube of agar-agar was liquefied, infected with Bacillus anthracis, and poured into a Petri dish. After solidification, a piece of iodine catgut was placed upon it. January 17, numerous colonies, but none within one and three-quarters inches of the catgut. January 18, a few scattered colonies around the margin of the space previously clear, but still there are no colonies within one inch of the catgut. Observations taken until January 21, but no further change noted, excepting an increase in the size of some of the superficial colonies.

EXPERIMENT 114.—January 16. A tube of agar-agar was liquefied, infected with Bacillus subtilis, and poured into a Petri dish. After solidification, a piece of von Bergmann catgut was placed upon it. January 17, numerous colonies, but none within a space, about one-third of an inch wide, surrounding the catgut. Observations taken until January 21, but no further change noted.

EXPERIMENT 91.—January 14. A tube of agar-agar was liquefied, infected with Streptococcus pyogenes, and poured into a Petri dish. After solidification, a piece of iodine catgut was placed upon it. January 15, a few colonies to be seen with the microscope, but only at the margins of the Petri dish. Observations taken until January 21, but no further change noted.

EXPERIMENT 92.—January 14. A tube of agar-agar was liquefied, infected with Streptococcus pyogenes, and poured into a Petri dish. After solidification, a piece of von Bergmann catgut was placed upon it. January 15, numerous colonies to be seen with the naked eye and microscope, but none in a space about one-half inch wide surrounding the catgut. Observations taken until January 21, but no further change noted.

EXPERIMENT 56.—January 10. Smears of Bacterium coli were made upon agar solidified in a Petri dish; upon these a piece of iodine gut was placed. January 11, numerous colonies, but none anywhere near the catgut. January 12, the colonies are larger than on January 11, but there is no extension towards the catgut. Observations taken until January 16, but no further change noted. (See illustration.)

EXPERIMENT 57.—January 10. Smears of Bacterium coli were made upon agar solidified in a Petri dish; upon these a piece of von Bergmann catgut was placed. January 11, growth on all smears almost up to the catgut, though not quite in contact with it. Observations taken until January 16, but only an increase in the size of the colonies noted. (See illustration.)

EXPERIMENT 58.—January 10. Smears of Staphylococcus aureus were made upon agar solidified in a Petri dish; upon these a piece of iodine gut was placed. January 11, growth on all smears distant from the catgut, but none anywhere near it. Observations taken until January 16, but only an increase in the size of the colonies noted. (See illustration.)

EXPERIMENT 59.—January 10. Smears of Staphylococcus aureus were made upon agar solidified in a Petri dish; upon these a piece of von

Bergmann catgut was placed. January 11, growth on all smears, almost up to the catgut, but not quite in contact with it. January 12, increase in the size of the colonies, and their extension towards the catgut was noted, so as to be almost in contact with it. Observations taken until January 16, but only an increase in the size of the colonies noted. (See illustration.)

EXPERIMENT 66.—January 11 is a repetition of Experiment 56, and is inserted here merely on account of the perfect illustration, which see.

EXPERIMENT 67.—January 11 is a repetition of Experiment 57, and is inserted here merely on account of the perfect illustration, which see.

EXPERIMENT 68.—January 11 is a repetition of Experiment 58, and is inserted here merely on account of the perfect illustration, which see.

EXPERIMENT 69. January 11 is a repetition of Experiment 59, and is inserted here merely on account of the perfect illustration, which see.

EXPERIMENT 93.—January 14. Smears of Bacillus anthracis were made upon agar solidified in a Petri dish; upon these a piece of iodine gut was placed. January 15, a few colonies developed near the ends of the streaks, but none anywhere near the catgut. Observations taken until January 21, but no further change noted. (See illustration. The colonies to the left of the catgut in this illustration are not of anthrax, but are accidental contaminations, developing sometime after the experiment.)

EXPERIMENT 94.—January 14. Smears of Bacillus anthracis were made upon agar solidified in a Petri dish; upon these a piece of von Bergmann catgut was placed. January 15, abundant growth on all streaks up to one-quarter of an inch from the catgut. Observations taken until January 21, but only an increase in the size of the colonies noted. (See illustration.)

EXPERIMENT 95.—January 14. Smears of Bacillus subtilis were made upon agar solidified in a Petri dish; upon these a piece of iodine gut was placed. January 15, growth at both ends of the streaks, but none anywhere near the catgut. Observations taken until January 21, but no further change noted. (See illustration.)

EXPERIMENT 96.—January 14. Smears of Bacillus subtilis were made upon agar solidified in a Petri dish; upon these a piece of von Bergmann catgut was placed. January 15, plate overgrown with extensive colonies in actual contact with the catgut. Observations taken until January 21, but no further change noted. (See illustration.)

EXPERIMENT 97.—January 14. Smears of Streptococcus pyogenes were made upon agar solidified in a Petri dish; upon these a piece of iodine gut was placed. January 15, a few colonies developed towards the ends of some of the streaks, all far away from the catgut. Observations taken until January 21, but no further change noted.

EXPERIMENT 98.—January 14. Smears of Streptococcus pyogenes were made upon agar solidified in a Petri dish; upon these a piece of von Bergmann catgut was placed. January 15, numerous colonies developed, but none nearer than one-half inch from the catgut. Observations taken until January 21, but no further change noted.

Even a hasty examination of the experiments just related, and particularly of the accompanying photographs, at once calls attention to two phenomena; first, the relatively large area, upon the plates made with iodine gut, which is free from any growth, more particularly when compared with the control plates made with von Bergmann catgut. It is, of course, difficult to express exactly in figures how much larger the area is around the iodine catgut than around the von Bergmann catgut; but I believe myself to be within safe limits if I judge that it is at least four times as great. Secondly, though relatively small, there is still an area free from growth also surrounding the von Bergmann catgut. It is self-evident that the large area surrounding the iodine catgut is due to the powerful antiseptic properties of the free iodine contained therein; and it was but natural to assume some similar agent, *e.g.*, $HgCl_2$, was also present in the von Bergmann catgut. Dr. Bookman, physiological chemist of Mount Sinai Hospital, was kind enough to undertake for me a chemical analysis. He found that one yard of No. 1 catgut prepared by the von Bergmann method contained an amount of mercury which would be equivalent to 0.008825 of $HgCl_2$; this will readily explain the relatively small sterile area upon the plates.

I am particularly pleased to acknowledge this work of Dr. Bookman, as at first I was at a loss to account for the non-appearance of any growth in the plates made with the von Bergmann catgut. I personally was always under the impression that in the von Bergmann catgut we are dealing with an aseptic catgut, and not with an antiseptic catgut; but the results obtained in the chemical analysis prove the contrary. It appears that the bichloride of mercury used in the preparation of the catgut enters into a chemical combination with the organic substances, probably some form of albuminate, which evidently has antiseptic properties as well.

It is patent to everybody that the sterility of the iodine catgut is due to the antiseptic action of the iodine contained therein; but it was of interest to me, also, to know just how much iodine was contained in a given piece of iodine catgut.

Analysis by Dr. Bookman revealed the presence of 0.025737 of iodine in one yard of No. 1 iodine catgut. If it is recollected that a 1 to 5000 aqueous solution of iodine is still a very powerful antiseptic, it will be seen that one and one-half inches of No. 1 catgut will be amply sufficient to render absolutely sterile 8 cubic centimetres of medium, the amount generally used for bacteriological purposes.

It might, and with a certain amount of justice, be argued that in the experiments just related, the iodine exerts merely an inhibitory action upon the development of the bacteria, and that there are still numerous active and living bacteria in the clear area surrounding the catgut, which are only temporarily prevented from developing, but which would still develop when placed in more favorable surroundings. In order to disprove such a possibility, I have made the following experiments:

EXPERIMENT A. EXPERIMENT 162.—January 29. A tube of liquefied agar-agar was inoculated with a virulent culture of Bacillus anthracis, and poured into a Petri dish. After solidification, a piece of iodine catgut was placed upon it. January 30, numerous colonies developed, but none in an area extending over one inch on either side of the catgut. February 1, no further change noted.

EXPERIMENT 164.—January 30. A liberal inoculation was made from the clear agar surrounding the iodine catgut in Experiment 162, and about one-half inch away from it, into bouillon. January 31, no growth. Observations taken until February 5, but no further change noted.

EXPERIMENT 166.—January 30. Repetition of Experiment 164 in agar and Petri dish also gave a negative result.

But even this series of experiments may not be considered absolutely conclusive, as it might be argued that the conditions with the bouillon in Experiment 164, or with the agar in Experiment 166, were still not sufficiently favorable for the development of the anthrax bacilli. I therefore supplemented them with the following animal experiment.

EXPERIMENT 172.—February 4. After proper preparation and antiseptic precautions, a small incision was made upon the back of a guinea-pig, and with dressing-forceps a small pocket was prepared. Into this there was buried a piece of the clear agar surrounding the catgut in Experiment 162, about one-half inch square and about one-sixteenth

of an inch thick. February 5, no reaction. February 11, animal still alive and perfectly well.

Surely in this test all the conditions favorable for the development of any bacteria were present; and if the high virulence of the particular anthrax culture used be considered, we must assume that death of the animal should have followed, provided there were still living, though undeveloped, bacteria in the clear space surrounding the catgut.

In corroboration of this fact, I might also adduce the argument that all of my plates were observed for a number of days in the thermostat, and that I have found that already after twenty-four hours, owing to the temperature of the thermostat, and owing to the chemical affinity free iodine has for the various salts contained in the nutritive media, the catgut has lost its black color, nor could I get the well-known reaction for iodine with starch. It follows therefore that any agency which the iodine may have upon the non-development of bacteria must be exerted in the beginning; assuming merely an inhibitory action, this would certainly cease after the iodine has been driven off by volatilization; but as no bacteria develop in the clear space even after long-continued observation, we must come to the conclusion that the iodine acts not merely as an inhibitory agent, but as a true bactericide.

I know full well that the human body is not a culture tube nor a guinea-pig, and that numerous other conditions, which exist in the human body and not in the Petri dish, must be taken into account; but I believe we may safely deduct this much from this series of experiments, namely, that the iodine catgut will, at least in a measure, assist in neutralizing accidental infections in wounds.

C. *Tests to show the Effects of Infected Catgut.*—I now come to the most interesting series of my experiments,—interesting because they were entirely unlooked for and surprising, and also because they are so very important from the surgeon's stand-point. This series of experiments goes to prove in a bacteriological sense that the iodine catgut is practically non-infectible. The importance of this point will be readily appre-

ciated when it is remembered that accidental contact-infections of the catgut are so manifoldly possible, that a careful supervision of any operation goes to show that these accidental contact-infections, in spite of all care to eliminate them, are not only not exceptional, but the rule. The surgeon's and assistants' hands, as well as the skin of the patient, can never be rendered absolutely sterile, but only relatively so. The surgeon and assistants may even avoid direct contact with the catgut by wearing rubber gloves, but the skin of the patient cannot be so protected, and yet the catgut, if used as a suture, must pass through it. This results, as we all know, in an occasional stitch abscess, and from time to time in more serious infections. I venture to say that even these may be eliminated with the aid of iodine catgut.

The method of procedure was the following: Bouillon cultures were made of the following actively growing bacteria: Bacillus coli; Staphylococcus aureus; Streptococcus pyogenes; Bacillus anthracis, and Bacillus subtilis. This culture was kept in the thermostat for twenty-four hours. At the expiration of this time, when an abundant growth had resulted, the culture was divided into two halves, and poured into sterile Petri dishes; into one dish there were placed about one dozen pieces of iodine catgut, about one inch in length, and into the other a similar number of von Bergmann catgut of the same length. Both dishes were then replaced for another twenty-four hours into the thermostat. At this time the excess of culture medium was poured off, and various tests made with the catgut (in the experiments this is called "wet catgut"); the balance was replaced for another twenty-four hours into the thermostat, and another set of experiments was made with it (in the experiments this is called "dry catgut").

EXPERIMENT 43.—January 5. Iodine gut infected with Bacillus coli "wet" planted into bouillon. January 6, no growth, nor at any time until January 14, when further observation was discontinued.

EXPERIMENT 44.—January 5. Von Bergmann catgut infected with Bacillus coli "wet" planted into bouillon. January 6, growth. Observations taken until January 14, but no further change noted.

EXPERIMENT 45.—January 5. Iodine gut infected with Staphylococcus

aureus "wet" planted into bouillon. January 6, no growth, nor at any time until January 14, when further observation was discontinued.

EXPERIMENT 46.—January 5. Von Bergmann catgut infected with Staphylococcus aureus "wet" planted in bouillon. January 6, growth. Observations taken until January 14, but no further change noted.

EXPERIMENT 115.—January 17. Iodine gut infected with Bacillus anthracis "wet" planted in bouillon. January 18, no growth, nor at any time until January 26, when further observation was discontinued.

EXPERIMENT 116.—January 17. Von Bergmann catgut infected with Bacillus anthracis "wet" planted into bouillon. January 18, no growth. January 19, growth. Observations taken until January 26, but no further change noted.

EXPERIMENT 117.—January 17. Iodine gut infected with Bacillus subtilis "wet" planted in bouillon. January 18, no growth, nor at any time until January 26, when further observation was discontinued.

EXPERIMENT 118.—January 17. Von Bergmann catgut infected with Bacillus subtilis "wet" planted in bouillon. January 18, growth. Observations taken until January 26, but no further change noted.

EXPERIMENT 119.—January 17. Iodine gut infected with Streptococcus pyogenes "wet" planted in bouillon. January 18, no growth, nor at any time until January 26, when further observation was discontinued.

EXPERIMENT 120.—January 17. Von Bergmann catgut infected with Streptococcus pyogenes "wet" planted in bouillon. January 18, growth. Observations taken until January 26, but no further change noted.

These ten experiments made with the two varieties of catgut, after having been literally soaked for twenty-four hours in a twenty-four-hour old culture of actively growing bacteria, show that the iodine content of the iodine catgut was sufficient at least to inhibit, if not destroy, the development of bacteria with which it came in contact, since all the experiments with the iodine catgut gave a negative result, while all the experiments with the von Bergmann catgut gave a positive result. As in actual practice, however, we are using the catgut dry, it was necessary to repeat all these experiments, also, with the dried catgut. Following were the results obtained:

EXPERIMENT 47.—January 6. Iodine gut infected with Bacillus coli "dry" planted in bouillon. January 7, no growth, nor at any time until January 14, when further observation was discontinued.

EXPERIMENT 48.—January 6. Von Bergmann catgut infected with Bacillus coli "dry" planted in bouillon. January 7, growth. Observations taken until January 14, but no further change noted.

EXPERIMENT 49.—January 6. Iodine gut infected with Staphylococcus

aureus "dry" planted in bouillon. January 7, no growth, nor at any time until January 14, when further observation was discontinued.

EXPERIMENT 50.—January 6. Von Bergmann catgut infected with Staphylococcus aureus "dry" planted in bouillon. January 7, no growth. January 8, growth. Observations taken until January 14, but no further change noted.

EXPERIMENT 121.—January 18. Iodine gut infected with Bacillus anthracis "dry" planted in bouillon. January 19, no growth, nor at any time until January 26, when further observation was discontinued.

EXPERIMENT 122.—January 18. Von Bergmann catgut infected with Bacillus anthracis "dry" planted in bouillon. January 19, no growth. January 20, no growth. Observations taken until January 26, but no further change noted. (The only negative experiment in the entire series!)

EXPERIMENT 123.—January 18. Iodine gut infected with Bacillus subtilis "dry" planted in bouillon. January 19, no growth, nor at any time until January 26, when further observation was discontinued.

EXPERIMENT 124.—January 18. Von Bergmann catgut infected with Bacillus subtilis "dry" planted in bouillon. January 19, growth. Observations taken until January 26, but no further change noted.

EXPERIMENT 125.—January 18. Iodine catgut infected with Streptococcus pyogenes "dry" planted in bouillon. January 19, no growth, nor at any time until January 26, when further observation was discontinued.

EXPERIMENT 126.—January 18. Von Bergmann catgut infected with Streptococcus pyogenes "dry" planted in bouillon. January 19, growth. Observations taken until January 26, but no further change noted.

I have repeated the experiments just related also with agar media; their object is merely to serve as a better object lesson. The procedure was the following: Agar-agar was liquefied and poured into Petri dishes. After solidification, a piece of the dry catgut, infected according to the method before described, was placed upon it, and the subsequent behavior noted. Following was the result of these experiments:

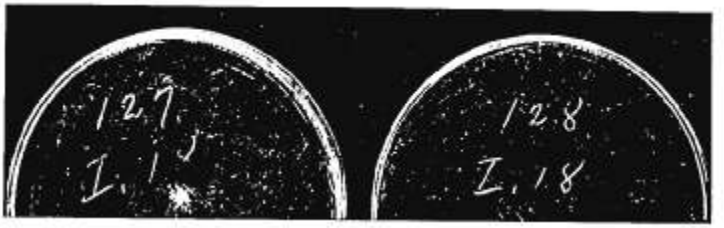
EXPERIMENT 72.—January 12. Iodine gut infected with Bacillus coli "dry" placed upon agar. January 13, no growth, nor at any time until January 17, when further observation was discontinued. (See illustration.)

EXPERIMENT 73.—January 12. Von Bergmann catgut infected with Bacillus coli "dry" placed upon agar. January 13, growth. Observations taken until January 17, but no further change noted. (See illustration.)

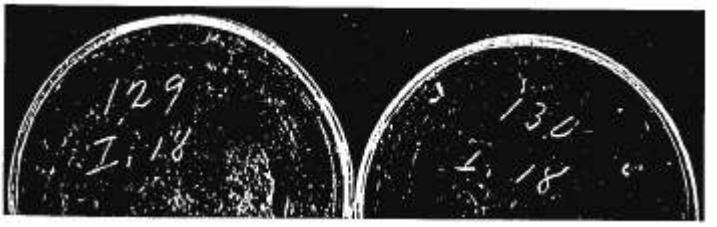
EXPERIMENT 74.—January 12. Iodine gut infected with Staphylococcus aureus "dry" placed upon agar. January 13, no growth, nor at any

No. 72. Iodine gut infected with Bacillus coli "dry" on agar.
No. 73. Von Bergmann gut infected with Bacillus coli "dry" on agar.

No. 74. Iodine gut infected with Staphylococcus aureus "dry" on agar.
No. 75. Von Bergmann gut infected with Staphylococcus aureus "dry" on agar.



No. 127. Iodine gut infected with Bacillus anthracis "dry" on agar.
No. 128. Von Bergmann gut infected with Bacillus anthracis "dry" on agar.



No. 129. Iodine gut infected with Bacillus subtilis "dry" on agar.
No. 130. Von Bergmann gut infected with Bacillus subtilis "dry" on agar.

time until January 17, when further observation was discontinued. (See illustration.)

EXPERIMENT 75.—January 12. Von Bergmann catgut infected with Staphylococcus aureus "dry" placed upon agar. January 13, growth. Observations taken until January 17, but no further change noted. (See illustration.) (In this illustration the large colony at the upper end is an accidental mould, but the small, fine colonies along the lower end are typical staphylococci.)

EXPERIMENT 127.—January 18. Iodine gut infected with Bacillus anthracis "dry" placed upon agar. January 19, no growth, nor at any time until January 26, when further observation was discontinued. (See illustration. No attention is to be paid to the accidental contamination to the right of this illustration, nor in the next illustration.)

EXPERIMENT 128.—January 18. Von Bergmann catgut infected with Bacillus anthracis "dry" placed upon agar. January 19, no growth. January 20, growth. Observations taken until January 26, but no further change noted. (See illustration.)

EXPERIMENT 129.—January 18. Iodine gut infected with Bacillus subtilis "dry" placed upon agar. January 19, no growth, nor at any time until January 26, when further observation was discontinued. (See illustration.)

EXPERIMENT 130.—January 18. Von Bergmann catgut infected with Bacillus subtilis "dry" placed upon agar. January 19, growth. Observations taken until January 26, but no further change noted. (See illustration.)

EXPERIMENT 131.—January 18. Iodine gut infected with Streptococcus pyogenes "dry" placed upon agar. January 19, no growth, nor at any time until January 26, when further observation was discontinued.

EXPERIMENT 132.—January 18. Von Bergmann catgut infected with Streptococcus pyogenes "dry" placed upon agar. January 19, no growth. January 20, growth. Observations taken until January 26, but no further change noted.

The thirty experiments last enumerated are of the utmost importance, because they more nearly approach the use of catgut in actual practice. They show that at least, as far as the bacteriological test is concerned, the iodine catgut is far superior to the von Bergmann catgut, inasmuch as it is absolutely "uninfectible." All experiments with the iodine catgut gave an absolutely negative result, while with one exception (Experiment 122) all experiments made with the von Bergmann catgut gave a positive result. Again, I would call attention to the fact that the living human organism is not a culture tube, and it would be wrong to transfer inferences from these test-tube and Petri dish experiments to the operating room; but

they certainly show this at least, that those constantly occurring, accidental, and unavoidable infections are of no harm if they occur with iodine catgut, while similar infections of the von Bergmann catgut may be productive of the greatest harm.

In addition to the above experiments, I have also made a few experiments with iodine gut after infecting it with pus from various sources. Of course, these experiments lose in actual value when compared with those just related, in which we deal with certain definite and positive infections; but they appeal perhaps more to the surgeon, as they deal with infections which might occur at any time in an operating room, or even in the course of an individual operation.

EXPERIMENT 51.—January 10. On January 9 I had occasion to operate a metastatic empyema, caused by streptococci, the presence of which was verified both by slides and cultures. A basin of the pus was caught in a sterile vessel, and in it there was placed a spool of iodine catgut. After an immersion of six hours it was removed and placed into a sterile bottle, with large amounts of the pus still adhering to it. Fourteen hours later (*i.e.*, twenty hours after beginning the experiment) a piece of the catgut about one inch in length was planted into bouillon. January 11, no growth, nor at any time until January 16, when further observation was discontinued.

To refute the possible argument that in this as in other experiments the amount of iodine contained in the catgut was sufficient to render the small quantity of bouillon antiseptic, the following experiment was made:

EXPERIMENT 64.—January 11. A piece of the catgut used in Experiment 51, about one inch in length, was planted into a large quantity (60 cubic centimetres) of bouillon, forty hours after the empyema operation. January 12, no growth, nor at any time until January 18, when further observation was discontinued.

EXPERIMENT 70.—January 12. Iodine catgut was liberally smeared in the pus of a freshly opened furuncle of the neck (staphylococcus in spreads), and one hour later a piece one inch in length was planted into bouillon. January 13, no growth, nor at any time until January 18, when further observation was discontinued.

EXPERIMENT 71.—January 12. Iodine catgut was liberally smeared in the pus of an axillary abscess (staphylococci in spreads), and one hour later a piece one inch in length was planted into bouillon. January 13, no growth, nor at any time until January 18, when further observation was discontinued.

EXPERIMENT 76.—January 13. The iodine gut used in Experiment 70 was allowed to remain in contact with the pus, and twenty-six hours later, by which time it had become perfectly dry, a piece one inch in length was planted into bouillon. January 14, no growth, nor at any time until January 21, when further observation was discontinued.

EXPERIMENT 77.—January 13. The iodine gut used in Experiment 71 was allowed to remain in contact with the pus, and twenty-six hours later, by which time it had become perfectly dry, a piece one inch in length was planted into bouillon. January 14, no growth, nor at any time until January 21, when further observation was discontinued.

EXPERIMENT 78.—January 13. Iodine gut was smeared in the pus of a freshly incised large periproctitic abscess, communicating by a fistulous tract with the rectum (numerous cocci and bacilli in spreads), and one hour later a piece one inch in length was planted into bouillon. January 14, no growth, nor at any time until January 21, when further observation was discontinued.

EXPERIMENT 80.—January 14. The iodine gut used in Experiment 78 was allowed to remain in contact with the pus for twenty-five hours, by which time it had become perfectly dry, and a piece one inch in length was planted into bouillon. January 15, no growth, nor at any time until January 21, when further observation was discontinued.

EXPERIMENT 82.—January '14. Iodine gut was smeared into the pus of a freshly incised suppurative arthritis of the elbow-joint, and one hour later a piece one inch in length was planted into bouillon. January 15, no growth, nor at any time until January 21, when further observation was discontinued.

On this occasion I repeated the experiment also with von Bergmann catgut, and, as was to be expected, obtained a positive result.

EXPERIMENT 83.—January 14. Von Bergmann catgut was smeared into the pus of a freshly incised suppurative arthritis of the elbow-joint, and one hour later a piece one inch in length was planted into bouillon. January 15, growth.

In addition, I have made numerous experiments in the following manner: Pieces one inch in length were cut with an ordinary old unsterilized pair of scissors, from spools of iodine catgut, which had lain some time for months in a not overclean laboratory drawer, and planted into bouillon, but at no time was a growth obtained.

All of the experiments just related show that at least, as far as culture experiments go, not only is the iodine catgut absolutely sterile, but also that it is absolutely impossible to infect it, either with cultures of known activity or with resistant spores, or with ordinary pus.

Advisedly and with caution have I used in my *résumé* the expression that these results are true as far as the culture experiments are concerned, as I expected that the objection would be raised that in an operation we would have to deal with conditions which materially differ from any laboratory experiment. This was brought to my attention by Dr. Lilienthal, of Mount Sinai Hospital, who conceded that the catgut was sterile, and also that it was uninfectible, provided sufficient time was given for the iodine to exert its antiseptic action. He argued that in the course of an operation infections of the catgut might occur, which catgut being used immediately thereafter, before the iodine had sufficient time to exert its bactericidal action, might possibly cause an infection in this manner. Dr. Lilienthal was of the opinion that a nearer approach to the actual use of the catgut could be obtained in the following manner: That catgut infected with various germs is inoculated into a nutritive medium, but is removed therefrom in a few seconds. While conceding the validity of the argument, I would not concede the validity of the experiment, but, *experimenti causa*, I have carried out the tests suggested, using both iodine and von Bergmann catgut; the result of which in brief is the following:

EXPERIMENT 133.—January 19. Immersion for a few seconds of iodine gut infected with Bacillus coli into bouillon was followed by no growth.

EXPERIMENT 134.—January 19. Immersion for a few seconds of von Bergmann catgut infected with Bacillus coli into bouillon was followed by a growth.

EXPERIMENT 135.—January 19. Immersion for a few seconds of iodine gut infected with Staphylococcus aureus into bouillon was followed by no growth.

EXPERIMENT 136.—January 19. Immersion for a few seconds of von Bergmann catgut infected with staphylococcus aureus into bouillon was followed by no growth.

EXPERIMENT 137.—January 19. Immersion for a few seconds of iodine gut infected with Bacillus anthracis into bouillon was followed by no growth.

EXPERIMENT 138.—January 19. Immersion for a few seconds of von Bergmann catgut infected with Bacillus anthracis into bouillon was followed by no growth.

EXPERIMENT 139.—January 19. Immersion for a few seconds of iodine gut infected with Bacillus subtilis into bouillon was followed by no growth.

EXPERIMENT 140.—January 19. Immersion for a few seconds of von Bergmann catgut infected with Bacillus subtilis into bouillon was followed by a growth.

While, as already stated, I do not concede the validity of the argument that the experiments just related are a closer approach to infections as they might occur accidentally in the course of an operation, they are of interest in so far that they also tend to prove that it is impossible to get infections with the iodine catgut in this manner; all the experiments with iodine catgut gave a negative result, while on the other hand two out of the five experiments with the von Bergmann gut (the coli and subtilis experiment) gave a positive result.

In order to determine the possibility of such infections, experiments would have to be done actually upon the human body; but, as this would be entirely too risky and dangerous, no one will reproach me with the incompleteness of my studies. I have attempted to approach this form of infection with animal experiments, and following is the result:

EXPERIMENT 148.—January 27. On January 26 I made a bouillon culture of an actively growing, virulent Bacillus anthracis, and permitted it to grow for twenty-four hours in the thermostat. On January 27 I made a small incision upon the back of a guinea-pig, and bluntly made therein a subcutaneous channel; into this I buried two pieces of iodine catgut about two inches in length, which had been dipped into the anthrax culture, and closed the opening with a suture. January 28. The animal looked and acted perfectly well, and, in spite of this extremely severe test, I had strong hopes that the animal might overcome the infection. In this I was disappointed, as on the following morning, January 29, the animal was found dead.

EXPERIMENT 147.—January 27. In this experiment I repeated in all details Experiment 148, with the exception that I used von Bergmann catgut. On January 28 the animal looked and acted sick and refused its nourishment. On the following morning, January 29, the animal was found dead.

It is seen, therefore, that both these experiments (148 and 147) gave a negative result, inasmuch that both animals died. Nor could I expect anything different; and I so ex-

pressed myself at the time I operated upon the animals. I know that sufficient of the culture adhered to the dripping wet catgut to kill any animal, and I also know that in the introduction of the catgut sufficient of the culture medium was wiped upon the wound at some distance from the iodine catgut to cause an infection and death. The only conclusion to be reached, therefore, is that both animals died in consequence of a surcharge of the infective medium; and I am sure every one will agree with me that this is not the way catgut infections occur in the course of an operation, even if we would concede the possibility of anthrax infection.

It was necessary, therefore, to find a method which would more nearly approach the conditions as they might occur in practice. I believe I have found it by proceeding in the following manner:

EXPERIMENT 170.—February 4. Two pieces of iodine gut, about two inches in length, were thoroughly moistened in a twenty-four-hour bouillon culture of virulent anthrax; they were then dried between folds of sterile blotting-paper, and immediately buried in a channel beneath the skin of the back of a guinea-pig. February 5, the animal looks and acts perfectly well. February 6, apparently no change in the condition and behavior of the animal. February 7, the animal was found dead in its cage.

EXPERIMENT 171.—February 4. Repetition of Experiment 170, with the difference that in place of iodine catgut von Bergmann catgut was used. February 5, the animal was found dead in its cage.

It is seen that the last two experiments (170 and 171) were followed by the same result as the more severe experiments (147 and 148); both animals, the one with infected iodine gut as well as the one with infected von Bergmann catgut, died. It is true that the former outlived the latter by forty-eight hours, but that is, and should be, no criterion. What we are looking for are positive results in the form of complete immunity, and not merely prolongation of life; at best, we are entitled perhaps merely to deduct so much from these experiments that the iodine catgut was sufficiently strong to neutralize some of the anthrax bacilli, but there still remained sufficient to eventually kill the guinea-pig. Even this,

however, would be some encouragement from the surgeon's point of view, as it must be recollected that, as a general rule, we are not working with catgut which has been soaked, like in the experiments related, in virulent anthrax cultures.

All in all, I do not see how we could imitate the conditions exactly to fulfil the objections raised by Dr. Lilienthal. It is true that I could perhaps repeat the experiments with bacteria, which are less fatal than anthrax, for instance, with the ordinary pus-forming germs, but I do not see that much would be gained by it. For instance, the presence of pus would by no means be proof of the inefficiency of the iodine catgut, as it might be argued that the purulent infection was introduced otherwise and not with the catgut. I confess, therefore, that, for the want of a good method, I am for the present unable to refute Dr. Lilienthal's argument.

The result of the various experiments carried out to prove the sterility of the catgut are to my mind so convincing that a general *résumé* is hardly indicated.

2. TENSILE STRENGTH.—Having proven the aseptic and antiseptic properties of iodine catgut, it remained for me to show that its tensile strength was not inferior, and perhaps superior, to other forms of catgut.

It is not sufficient to state that in actual use we have found that the catgut was sufficiently strong for all the requirements, or all the demands made upon it; nor can much value be put upon the statements of others that the catgut was too weak, and that it has lost a considerable part of its tensile strength. A great deal depends upon the personal equation of the individual who is using or testing it. If "A" wishes to prove that any catgut is strong, he does not pull quite as hard as "B," who wishes to prove that the catgut is weak, and *vice versa*. The only way to either prove or disprove anything of this nature is by actually and accurately measuring the amount of pulling force applied. This would be comparatively easy with most substances, but with catgut it is surrounded by almost insurmountable difficulties. This is due to many facts about

catgut, all of which have a most important bearing upon its tensile strength. First, there exist no accurate standard sizes of catgut. It is true that we can buy in the market so-called standard sizes, which are variously labelled from 00 upward; but in reality this does not mean anything, as anybody can readily convince himself by simply glancing at a number of rolls. I have, for instance, frequently examined packages of catgut marked for a certain size, and found all possible variations, both above and below the size stated; in some of the larger sizes measured (No. 2) with an accurate micrometer the variations were as much as fifteen one-hundredths of a millimetre in diameter. Fifteen one-hundredths of a millimetre may appear a triviality, but in reality it makes a very great difference, as the strength of a given piece of material varies not as does the diameter, but as does the square of the diameter. Second, there is an important variation in size, not only between different rolls, but also in different parts of the same roll, and we find thinner portions alternating with thicker portions; and it is perhaps needless to add that a given piece of the catgut is only as strong as its weakest portion. Third, that the strength of the catgut depends not only on its diameter, but also upon other undetermined qualities, which vary not only in different rolls, but also in different portions of the same roll, *e.g.*, light portions alternate with dark portions, translucent with almost transparent portions, alternate with opaque portions. Finally, that the strength of the catgut depends upon the workmanship originally used in its preparation; I mean how tightly it was originally twisted to get a diameter of a certain size. It is self-evident that of two pieces of catgut of equal diameter that one will be stronger which is twisted tighter, because in reality there is much more catgut substance in it. I have paid a good deal of attention to this point, and finally, by a mere glance, I could tell beforehand which catgut would be strong and which weak. All in all, it is seen that this was by no means an easy question to solve.

But after making due allowance for these qualities inherent to the catgut, there arose a further difficulty, inasmuch

as I was not in possession of any apparatus by which I could accurately determine its tensile strength. The crude affairs that I was able to rig up were not sufficiently accurate, and

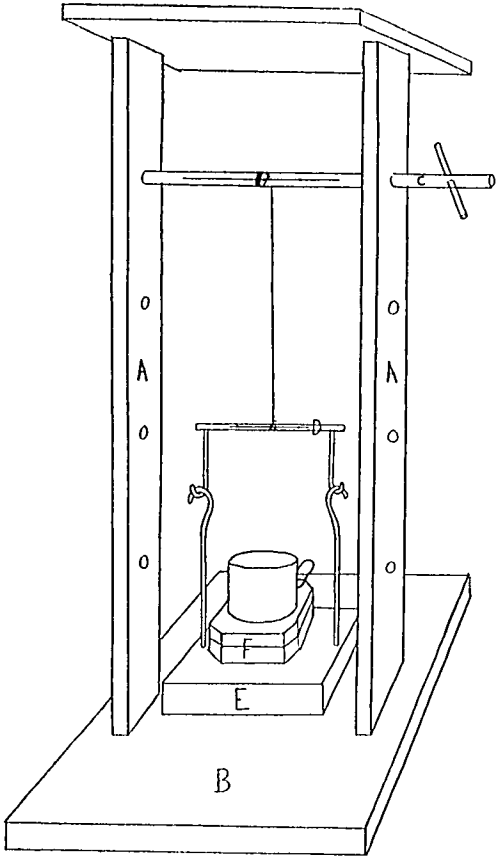


FIG. 1.—Apparatus to test tensile strength of catgut.

were so cumbersome that I could not make sufficient headway. In this dilemma I consulted Professor Hallock, of the Department of Physics, at Columbia University; as no apparatus was

on hand to determine the tensile strength of catgut, Dr. Forbes, of the Department of Physics, of Columbia University, very kindly designed and constructed the following apparatus for me (Fig. 1).

The instrument consists of two parallel vertical bars (A, A) firmly fixed in a stand (B) and connected above. The sides of A and A are perforated at different heights, and through any pair of these holes a cross-bar (C) made of brass may be firmly fixed; the latter is perforated by a long slit and fine openings, through which the catgut may easily be threaded; by a few rotations of C the catgut will be held solidly, and yet will hang only in a tangent from the round surface of C, so as not to be cut by any sharp edge. The other end of the catgut is then fixed in a similar manner to another brass bar (D) which supports a suspended platform (E). This platform in turn supports any number of weights (F) which may be placed upon it. On top of the weights there rests a small cup into which shot may be poured. When the amount of shot poured in is sufficient to break the catgut, it is weighed and the amount added to the original weights first placed upon the platform, plus the weight of the other suspended parts of the apparatus, which, of course, have previously been determined.

While this apparatus is by no means perfect, we believe it to be more devoid of gross errors than apparatus which work with a spring-balance, as it enables us to get nearer to the actual breaking strength of an individual piece of catgut. Soon after the construction of the apparatus, however, I found that a great deal depended on the intrinsic characteristics of the catgut, and that it would not do to merely measure a single piece of the catgut of a given size, and from it to draw the conclusion that this size of catgut has a given breaking-point. The figures vary so much, that the only way to determine this was to determine the breaking-point of many rolls, and from different parts of the same roll, and then to draw the final deduction from the grand average.

Following is the result of my measurements:

NUMBER 0 CATGUT.

Iodine Catgut. Grammes.	Von Bergmann Catgut. Grammes.	Raw Catgut. Grammes.
2827	3595	2801
3778	3691	3226
2616	2731	3216
4241	3136	
3791	3013	
3576	2912	
3696	3078	
4182	3126	
4017	2987	
3928	3175	
Av'age, 3665	3180	3081

NUMBER 1 CATGUT.

Iodine Catgut. Grammes.	Von Bergmann Catgut. Grammes.	Raw Catgut. Grammes.
4723	4681	4561
4067	3866	4866
4916	4421	5456
6186	4567	
5796	4658	
4911	4649	
5941	5018	
6076	4925	
5866	4532	
5978	4612	
Av'age, 5446	4592	4961

NUMBER 2 CATGUT.

Iodine Catgut. Grammes.	Von Bergmann Catgut. Grammes.	Raw Catgut. Grammes.
7150	7291	6896
7251	7520	6686
6526	7440	6496
7080	6975	
8716	6942	
6826	7257	
7043	7261	
7251	7223	
7120	6711	
8239	6709	
Av'age, 7320	7132	6526

While this gives us an excellent and very fair idea of the tensile strength of the catgut as it is used for suture material, it is by no means the tensile strength of the catgut as it is used for ligatures, particularly for tying heavy pedicles; because in the latter we have to deal, in addition, with the knot problem, which was found to be a most important element in the tensile strength of catgut. It was necessary, therefore, to repeat all of these experiments with the addition of a knot in the catgut measured; for the sake of simplicity only a single knot was tied; no doubt a surgeon's knot would give still greater differences.

Following was the result of these measurements:

NUMBER 0 CATGUT.

Iodine Catgut. Grammes.	Von Bergmann Catgut. Grammes.	Raw Catgut. Grammes.
2146	Less than 1000 *	2076
2151	Less than 1000 *	2021
2166	Less than 1000 *	1856
2351	2346	
2306	2161	
2243	2246	
2116	2361	
2296	2111	
Av'age, 2220	2244	1984

NUMBER 1 CATGUT.

Iodine Catgut. Grammes.	Von Bergmann Catgut. Grammes.	Raw Catgut. Grammes.
2821	3068	3230
2786	3148	2871
2655	4106	2886
3783	2900	
3113	3801	
3491	3946	
4321	2995	
4196	3161	
4229	4120	
4176	3221	
Av'age, 3557	3446	2996

* Not figured in the average.

NUMBER 2 CATGUT.

Iodine Catgut. Grammes.	Von Bergmann Catgut. Grammes.	Raw Catgut. Grammes.
4431	5636	3961
4885	5541	3513
4011	5840	3928
4138	4005	
4126	5311	
4081	5124	
4951	5146	
4306	5634	
5356	5214	
5606	5139	
5066	5071	
5184	4923	
Av'age, 4678	5217	3800

The tests with the unknotted catgut, in spite of the great variability in strength, show that the raw catgut is by far the weakest of the three, and that the iodine gut is by far the strongest; this is particularly the case with the smaller sizes, the size most frequently used both as suture and ligature material.

If we now turn our attention to the knotted catgut, we again find that the raw catgut is by far the weakest; Numbers 0 and 1 have practically the same tensile strength if prepared with iodine as with the von Bergmann method, though even here there is some advantage in favor of the iodine catgut; but with the Number 2 catgut there is evidently some advantage in favor of the von Bergmann catgut. I believe, however, that this is merely accidental, as in some spools the iodine catgut gave just as high values as the best of the von Bergmann catgut. It is not impossible that more extensive measurements will equalize these values.

All in all, I am perfectly satisfied that the iodine catgut has not only not lost any of its tensile strength, but apparently it has materially gained.

3. METHOD OF PREPARATION.—Under this heading I can only repeat what I have already stated in my article previously referred to, viz., " The preparation of this catgut is simplicity

itself." But, for the sake of completeness and because of a slight modification in its preservation, it may perhaps not be amiss if I again go into detail regarding this point. The catgut, just as it is bought from the dealers, *i.e.*, without removing the fat, is loosely wound, preferably in a single layer, on to the spool, and tied at both ends in order to prevent unravelling. It is then immersed for eight days in a solution of iodine, one part; iodide of potassium, one part; distilled water, one hundred parts. (The solution is prepared by dissolving the iodide of potassium in a small quantity of the water, to which the iodine, previously finely pulverized, is added, and the whole diluted up to one hundred parts.)

According to Claudius's directions, the catgut was preserved in the original solution without any change; but as already stated, having found that after long-continued immersion in the solution the catgut loses some of its tensile strength, it was necessary to obviate or circumvent this drawback. This was done in a very simple manner, inasmuch as all that was necessary was to remove the catgut from the solution at the end of the eight days, and to preserve it thereafter merely dry in a sterile vessel, preferably in one not exposed to the light. (If necessary, the drying process might be hastened by placing to one side of the vessel in which the catgut is kept a small vial containing a little sulphuric acid.) In short, formerly we used a catgut which was wet, and by the newer method we use it dry.

It is used dry just as it is cut from the spool, without any previous immersion in carbolic solution or sterile water. Any unused catgut may be resterilized on a future occasion.

That this method of preparation is simple no one can deny; that it is extremely cheap, itself no mean item, particularly in large hospitals, where quantities are used, is also self-evident; one gallon of the solution, requiring 608 grains of iodine and an equal amount of iodide of potassium, costing only forty-two cents.

It is important to keep the solution in well-stoppered bottles or jars because the iodine is volatile, as can be seen by

the purple color of the atmosphere on top of the solution, and in time it deteriorates. Solutions good enough to use should in bulk have a deep brown, almost black color; any solution not corresponding to these physical requirements should be discarded.

The new method of preservation has produced also a change in the physical properties of the catgut, and, I regret to say, in some respects this change is a slight disadvantage; but even then it is better than catgut which is used out of alcohol. At present it is of a deep brown, almost black color, and still retains the characteristic odor of iodine; it is perfectly smooth, not swollen, as one might expect from its immersion in an aqueous solution. The old Claudius catgut was exceedingly convenient to use, as it did not kink, nor curl up like catgut used from alcohol; but this newer catgut is somewhat stiff, like a fine wire, but it has no tendency to kink up, and particularly when it is used as a suture it soon becomes soft and straight. All in all, a long-continued use of it has proven to me its superiority also in this direction over alcohol catgut.

4. Absorption.—Regarding this point, we have not made any recent observations. From a practical stand-point, I may say that the knots stay tight and do not tend to untie or loosen, and we have never seen any untoward symptoms which could be traced to a too early or too late absorption.

In this connection it might be of interest to mention that Dr. Bookman has attempted to gain experimentally some idea regarding its absorption, and he found that the von Bergmann catgut was completely digested in twenty-four hours in artificial gastric juice (pepsin and HCl); while on the other hand the same amount of iodine catgut was only partially disintegrated in seventy-two hours. From this we would be entitled to conclude that the iodine catgut is more resistant to absorption than the von Bergmann catgut, were it not for the fact that conditions in the body are different from the test-tube; in the latter we have a definite quantity of digesting fluid, but in the former we have leucocytes and constantly changing currents, which no doubt materially aid in absorp-

tion. In general, we may say that there is no material difference regarding the time of absorption between this and catgut prepared by other methods.

DISADVANTAGES.—Of these I know none, but, in order to prevent any misconception, it will perhaps be wise if I briefly mention those possibilities which might be raised against it.

The toxic effect of the iodine might cause some anxiety in the minds of some surgeons. There need be no fear on this account, because, first, even in the most extensive operation, *e.g.*, radical operation for carcinoma of the breast, the toxic dose can never be reached; second, because the iodine is divided so minutely that it quickly enters into a chemical combination with the salts of the body fluids, and forms only innocuous iodine compounds, etc., and third, because of late, after being so astonished at the almost marvellous antiseptic properties of the iodine solution, I have in a large number of cases used iodine solution for dressing wounds, using at each dressing large quantities of gauze dipped into iodine solution, but in no instance did I find even the slightest trace of irritation. (I may state here that I am now at work experimenting extensively with iodine gauze as a dressing, and thus far my experiments are so encouraging that I intend to publish the results at some future date.) For the reasons stated, I may also reply to the objections of those who fear that the iodine may act as an irritant upon the tissues.

The odor of the catgut and the staining of the linens are so trivial that they do not even merit discussion; particularly is this true of the latter, as by experience we have found that the stains are not permanent and readily disappear in the laundrying process.

I believe that our clinical experience and the experimental work as related in this paper fully justify the following conclusions:

1. The "dry" iodine catgut is absolutely sterile.
2. It is impossible to infect it by ordinary means.
3. Its imbibition with iodine is not sufficient to act as an irritant upon the tissues.

4. Its tensile strength is superior to raw catgut and to that prepared by the sublimate-alcohol method.

5. It is easily and cheaply prepared.

6. It is absorbed only after it has served the purposes for which it was intended.

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